Art. IV.—*The Tertiary Deposits of the Aire and Cape Otway.*

By T. S. HALL, M.A.,

Demonstrator and Assistant-Lecturer in Biology in the University of Melbourne;

AND

G. B. PRITCHARD,

Lecturer in Geology in the Working Men's College.

(With Plate VI.)

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Previous Notices.

In 1864, during the absence from the colony of Mr. Selwyn who was visiting England on leave, the duties of Director of the Geological Survey devolved on Mr. Aplin, the senior field geologist, and yielding to the public demand for more rapid surveys than were being executed in the careful quarter-sheet work inaugurated by his chief, he instructed Messrs. Daintree and Wilkinson, who had just completed their work in the neighbourhood of Ballan and Bacchus Marsh, to examine and report on the Cape Otway District. The only visit hitherto paid by any of the staff to the district was one made by Mr. Selwyn in 1858, when he examined the coast-line as far as Apollo Bay (1, p. 11). Before arrangments could be completed Mr. Daintree finally quitted Victoria for Queensland, and Mr. Wilkinson was placed in charge of the party, with Mr. R. A. F. Murray as assistant (2, p. 11). Wilkinson sent in a preliminary report (3 and 4) and then a more detailed one (5) accompanied by a section and map (6). Duncan reprinted (7) that part of the detailed report which dealt with what were termed the Miocene beds by Wilkinson, reproducing a part of the section but omitting some of the explanations and thus misleading Messrs. Tate and Dennant who did not consult Wilkinson's original reports (12, p. 115). In 1873 Mr. F. M. Krausé partially surveyed the country to the east of Cape Otway but does not seem to have gone further west

than Apollo Bay (9). He published a sketch map (10) in which he apparently relied on Wilkinson's survey for the details of the country about the Aire River. By neglecting a thickness in places of about 200ft. of dune rock, the æolian origin and extent of which are clearly indicated by Wilkinson, he has shown a large area occupied by the miocene of the survey. As regards the courses of the streams through the Aire Marsh Wilkinson's map, it may be mentioned, though the oldest, is the most correct; Krausé's being singularly inaccurate both here and elsewhere, a fact doubtless due to the enforced rapidity of the survey.

Mr. R. A. F. Murray, who had accompanied Wilkinson on his survey, gives in 1887 (11) a few further particulars, the outcome apparently of some unofficial visit to the Ford.

In 1895 Messrs. Tate and Dennant visited the Otway section (12 and 13), but though they report that they carefully examined the coast-line they were unable to find any of the outcrop west of the Aire indicated by Wilkinson, with the exception of the one in front of Mr. Robinson's house. As will be seen in the sequel all the latter author's localities, with perhaps one exception, are visible now just as he described them over thirty years ago.

In January, 1897, the present authors spent about a fortnight at the Aire, and found that Wilkinson's report and map were excellent guides to the locality which we purpose describing in some detail.

The mesozoic sandstones which occupy such a large area of the Otway district, are interrupted between Cape Flinders and Castle Cove by newer rocks which descend to the shore and extend inland for several miles, occupying a basin in the older series. In these newer rocks Wilkinson recognised three distinct members:—A set of marine and freshwater beds which he regarded as miocene and which in common with Messrs. Tate and Dennant we refer to as eocene; another, consisting of ferruginous conglomerates and sandstones flanking the slopes of the mesozoic rocks, capping the lower hills and which be called pliocene tertiary (5, p. 25); and lastly, the dune rock.

To the S.E. of the mouth of the Aire the coast is occupied by sand dunes with a few patches of dune rock on the beach and near the river mouth itself. In places on the front of the cliffs

the loose sand has been removed and it is seen that the greater part of the high land is formed of the consolidated rock. The dune rock occupies a large area on the Otway side of the river and the park like country is in strong contrast to the heavily timbered mesozoics further inland. Krausé has coloured the sea front as mesozoic but no trace of rocks of this age are seen between Cape Flinders and Castle Cove. On the west of the river the high sea cliffs are formed of dune rock weathered into fantastic crags and precipices, bare in some places and in others clothed with low and almost impenetrable scrub. The cliffs rise to a height of about 200ft. The eocene rocks which underlie the dune rock near Castle Cove nowhere rise to more than about 30ft. above sea level, while the high land between the sea and the Aire Marsh is almost entirely composed of dune rock of at least 200ft. in thickness. The whole of this cover is neglected by Krausé who maps it as miocene (of the survey).

Eocene.

It will be convenient to consider separately the localities which we examined.

Spud Point.

This point is formed by a small outcrop of eocene limestone which rises some 30ft. above the Aire Marsh and forms a tongue shaped area a few acres in extent. On its northern border the mesozoic rocks rise as a steep escarpment to a height of over 200ft. The outcrop is some 300 yards from Mr. Robinson's house and is the one alluded to by Messrs. Tate and Dennant. The rock consists of a yellow polyzoal limestone, the fossil fragments being much comminuted and mixed with quartz grit and pebbles up to a cubic inch in size, most of these being well rounded. The limestone is in places very hard and contains rounded concretionary masses of glazed limonite which are sometimes a couple of inches in diameter and from their resemblance to potatoes probably give the point its local name. In places a glazed deposit of limonite spreads over the joint faces in broad patches. Identifiable fossils are scarce, the rock being principally composed of worn polyzoa and stems of *Isis*. The stratification is not very clear but is apparently horizontal.

The following fossils were obtained :—

Corals.

Isis, sp.

Echinoidea.

Lovenia forbesi, Woods and Duncan.
Cyclaster archeri, T. Woods.
Eupatagus rotundus, ? Laube.
Scutellina patella, Tate.
Cidaroid spines.

Polyzoa. Abundant.

Brachiopoda.

Rhynchonella squamosa, Hutton.
Magellania grandis, T. Woods.
,, furcata, Tate.
,, insolita, Tate.
Magasella compta, G. B. Sowerby.

Lamellibranchiata.

Ostraea, sp.
Placunanomia sella, Tate.
Hinnites corioensis, McCoy.
Pecten murrayanus, Tate.
Pecten foulcheri, T. Woods.
,, sp., *aff.*, peroni.
Lima bassii, T. Woods.
Spondylus gaederopoides, McCoy.
Pectunculus laticostatus, Q. and G.
Cardium sp., *aff.*, C. hemimeris.

Gastropoda

Cypraea, sp. (casts).
Pleurotoma, sp.
Cassidaria wilsoni, Tate.
Thylacodes, sp.
Voluta, sp. (cast.)

The cast of Voluta is in the possession of Mr. Robinson of the Aire Station and is related to V. stephensi, Johnston. This is apparently the specimen referred to by Messrs. Tate and Dennant as V. mortoni, and if so is an identification which we cannot accept.

Fishing Point.

For about a mile inland from the mouth of the Aire the country is occupied by sand dunes. For a couple of miles further the eocene rocks crop out on the low hills forming the eastern borders of the marsh. Possibly they extend a little further but the dense nature of the vegetation together with the character of the rocks as we went inland induced us to go no further than where Wilkinson had indicated the last outcrop. As far north as Fishing Point the rocks consist of clay beds intercalated with fine grained yellow limestone, gritty polyzoal rock and ferruginous grit, the grains reaching the size of a pea. Small landslips are common on the face of the low hills, and on the fresh ones we secured a fair number of fossils. The stratification appears to be quite horizontal, while with regard to the fossils it is interesting to note that Murray (11, p. 101) referred the beds to the oligocene of the survey, correlating them with those of the Gellibrand, Mornington and the Moorabool Valley, and thus indicating the close relationship which undoubtedly exists between them.

The following fossils were obtained:—

Foraminifera. Several forms.

Corals.

Placotrochus deltoideus, Duncan.
,, elongatus, Duncan.
Flabellum victoriae, Duncan.
Notocyathus australis, Duncan.
,, excisus, Duncan.
,, viola, Duncan.
Conosmilia anomala, Duncan.

Echinoidea.

Cidaroid plates and spines.

Annelida.

Calcareous worm tubes.

Crustacea.

Crab chelae.
? Balanus, sp.

Polyzoa. Common.

Brachiopoda.

Magellania divaricata, Tate.

Magasella compta, G. B. Sow.
Terebratulina scoulari, Tate
,, catinuliformis, Tate.
Rhynchonella squamosa, Hutton.

Lamellibranchiata.

Dimya dissimilis, Tate.
Placunanomia ione, Gray.
,, sella, Tate.
Pecten yahlensis, T. Woods.
,, murrayanus, Tate.
,, foulcheri, T. Woods.
,, sturtianus, Tate.
,, polymorphoides, Zittel.
,, zitteli, Hutton.
Lima bassi, T. Woods.
Spondylus pseudoradula, McCoy.
Nucula atkinsoni, Johnston.
Nuculana apiculata, Tate.
Limopsis belcheri, Adams and Reeve.
Pectunculus cainozoicus, T. Woods.
,, laticostatus, Q. and G.
Barbatia crustata, Tate.
Plagiarca cainozoica, Tate.
Cucullaea corioensis, McCoy.
Trigonia subundulata, Jenkins.
,, tubulifera, Tate.
Crassatella dennanti, Tate.
,, communis, Tate.
Cardita polynema, Tate.
,, delicatula, Tate.
Diplodonta subquadrata, Tate.
Chama lamellifera, T. Woods.
Chione cainozoica, T. Woods.
Meretrix eburnea, Tate.
Myadora tenuilirata, Tate.
Corbula ephamilla, Tate.

Gastropoda.

Typhis evaricosus, Tate.
,, acanthopterus, Tate.

Murex velificus, Tate.
„ eyrei, T. Woods.
„ trochispira, Tate.
„ amblyceras, Tate.
„ asteriscus, Tate.
„ lophoessus, Tate.
Muricidea polyphyllus, Tate.
Argobuccinum maccoyi, Pritchard.
Lotorium woodsi, Tate.
„ annectans, Tate.
„ tortirostris, Tate.
„ cyphus, Tate.
„ acanthostephes, Tate.
„ craspedotus, Tate.
„ foliaceus, Tate.
„ senticosus, Tate.
Fasciolaria decipiens, Tate.
Sipho crebregranosus, Tate.
Siphonalia longirostris, Tate.
Euthria ino, Tate.
Zemira præcursoria, Tate.
Nassa tatei, T. Woods.
Voluta hannafordi, McCoy.
„ maccoyi, T. Woods.
„ halli, Pritchard.
„ conoidea, Tate, var.
„ antiscalaris, McCoy.
Mitra leptalea, Tate.
„ paucicostata, Tate.
„ semilaevis, Tate.
Marginella propinqua, Tate.
„ winteri, Tate.
„ wentworthi, Tate.
„ micula, Tate.
„ cassidiformis, Tate?
Ancillaria pseudaustralis, Tate.
„ semilævis, T. Woods.
Columbella funiculatus, T. Woods.
„ cainozoica, T. Woods?

Cancellaria calvulata, Tate.
,, gradata, Tate.
,, exaltata, Tate.
,, etheridgei, Johnston.
,, varicifera, T. Woods.
Bathytoma rhomboidalis, T. Woods.
Teleochilus gracillimum, T. Woods.
Pleurotoma murndaliana, T. Woods.
,, trilirata, Harris.
,, optata, Harris.
,, clarae, T. Woods.
Drillia trevori, T. Woods.
Mangelia obsoleta, Harris (?)
Clathurella obdita, Harris.
,, bidens, T. Woods
Conus heterospira, Tate.
,, hamiltonensis, Tate.
Cypraea leptorhyncha, McCoy.
,, contusa, McCoy.
,, brachypyga, Tate.
Trivia avellanoides, McCoy.
Semicassis sufflata, T. Woods.
Cassis exigua, T. Woods.
Natica hamiltonensis, T. Woods.
,, polita, T. Woods.
,, sub-noae, Tate.
,, subinfundibulum, Tate.
,, substolida, Tate.
Crepidula unguiformis, Lamarck.
Solarium wannonensis, T. Woods?
Turritella platyspira, T. Woods.
,, acricula, T. Tate, var.
Tenagodes occlusus, T. Woods.
Eulima danae, T. Woods.
Niso psila, T. Woods.
Mathilda transenna, T. Woods.
Cerithium apheles, T. Woods.
Newtoniella cribarioides, T. Woods.
Liotia roblini, Johnston.

Tinostoma parvula, T. Woods?
Bullinella exigua, T. Woods.
,, paucilineata, Cossman.
Subemarginula occlusa, Tate.
Styliola rangiana, Tate.

Scaphopoda.

Dentalium mantelli, Zittel.
,, subfissura, Tate.
,, aratum, Tate.

Corals	7
Echinoidea	1
Annelida	1
Brachiopoda	5
Crustacea	2
Lamellibranchiata	31
Gastropoda	85
Scaphopoda	3
	135

The Calder Limestones.

On the northern side of a small creek which enters the marsh about three quarters of a mile above Fishing Point the strata become more calcareous and the rocks in places have a lithological resemblance to the polyzoal limestones of Waurn Ponds. In other places they are more earthy and are more than usually devoid of molluscan remains. We gathered a few fossils, most of which were obtained from a low wall of rock about fifteen feet high on the northern slope of the spur.

As at Fishing Point the strata are nearly horizontal and thus present a marked difference from the highly inclined beds of the coast sections near at hand, while the distinction is as clearly marked by the palaeontological evidence.

The following is a list of fossils found :—

Corals.

Isis, sp.

Echinoidea.

Eupatagus rotundus, Laube.
Psammechinus woodsi, Laube.
Scutellina patella, Tate.

Brachiopoda.

Magellania grandis, T. Woods.
Terebratulina catinuliformis, Tate.
Magasella compta, G. B. Sowerby.
Rhynchonella squamosa, Hutton.

Lamellibranchiata.

Placunanomia sella, Tate.
Dimya dissimilis, Tate.
Pecten yahlensis *var* semilaevis, McCoy.
,, murrayanus, Tate.
,, foulcheri, T. Woods.

The Aire Coastal Sections.

For a little more than half a mile westward from the river mouth nothing but dune rock is seen on the beach which is impracticable except at low tide, and even then the passage is rough, as the enormous blocks of dune rock, weathered into sharp points, lie piled in the wildest confusion. Then a small sandy bay is reached, to which we afterwards found access could be easily gained from the downs above. The best way to reach it is to follow a fence which runs to the edge of the cliffs from the stockyard which is situated on the landward slope. About two hundred yards west of the fence a cattle track goes down to the beach. On the eastern side of the bay among the tumbled blocks of dune rock is a small exposure of black clays. This lies on the shoreward side of a prominent pinnacle, about thirty feet high, which is probably what is marked as the Sentinel Rock on Wilkinson's map. The strata consist of black and grey sandy clays with pyrites, gypsum and what appeared to be copiapite.

There is in places a good deal of carbonaceous matter, and the well-rounded sand-grains are at times as large as a pea. There is about twenty-five feet in vertical thickness exposed, and the outcrop is about a chain in length. We could not find any beds showing beneath these clays, and as the dip is E. 35° N. at 12°, the reverse of Wilkinson's observations, it is evident that it is not

the outcrop which he noted and which we were unable to discover. (5, p. 23). As that author points out the physical appearances of the deposit are the same as those of the Point Addis clays on which the polyzoal limestone rests and he referred both to the same horizon. A few chains S.E. of this point we found a loose block of Eocene limestone containing an umbilicated *Nautilus* about six inches in diameter and *Trigonia subundulata*, but could find no outcrop.

Wilkinson's No. 4 Locality.

About three quarters of a mile west of the outcrop of lignitic clays polyzoal limestone crops out extensively on the beach and is Wilkinson's No. 4 locality. The beds dip south-easterly, the strike being at right angles to the coast-line, and as hard and soft beds alternate fairly regularly the platform of rock which is exposed by the falling tide is furrowed like an old ploughed field and presents a striking dissimilarity from the dune rock which occurs elsewhere in the neighbourhood. A belt of sandy beach, fifteen yards wide, intervenes between this platform and the deposit at the foot of the cliffs where the tabular masses rise as high as one's head and are crowded with fragmentary fossils. To the N.W. the limestone overlies argillaceous rocks, of which there is only a small outcrop rising not far above extreme high water mark. The section from above downwards is :—

54ft. 0in. of polyzoal limestone with softer bands; full of quartz, grit and rounded pebbles.
6in. concretionary limonite with well rounded quartz pebbles.
2ft. 0in. clay and limestone.
6in. limestone.
1ft. 6in. grey clay.
6in. gritty limestone.
3ft. 0in. grey clay.
1ft. 0in. yellow limestone with polyzoa.
6in. clay.
9in. yellowish limestone.
6in. grey clay.
1ft. 0in. concretionary limestone with brachiopods and echinoids.

3ft. 6in.	grey clay with *Turritellas.*
1ft. 0in.	fawn coloured limestone.
4ft. 0in.	grey sandy clay, rich in fossils.
1ft. 0in.	grey clay with abundant polyzoa.
2ft. 0in.	fawn coloured hard limestone with small pockets of clay, with polyzoa, brachiopods and corals.
15ft. 0in.	dark grey clay, cutting like new cheese and becoming very hard on drying. Fossils scarce, principal ones Turritella aldingæ scaphopods and pteropods with large unbroken pieces of delicately branched polyzoa.
Total 92ft. 3in.	

The dip of the beds is S. 25° E. and varies from 18° to 20°.

The following fossils were obtained :—

Corals.

Graphularia senescens, Tate.
Conosmilia striata, Duncan.
Placotrochus elongatus, Duncan.
Notocyathus viola, Duncan and Woods.
Flabellum distinctum, Edw. and H.
Balanophyllia campanulata, Duncan.
„ selwyni, Duncan.
„ cylindrica, Michelotti.
Cycloseris tenuis, Duncan.

Echinoidea.

Cidaris (Leiocidaris) australiae, Duncan.

Brachiopoda.

Terebratula vitreoides, T. Woods.
Magellania insolita, Tate.
Terebratulina triangularis, Tate.

Lamellibranchiata.

Pectunculus cainozoicus, T. Woods.
„ laticostatus, Q. and G.
Myadora tenuilirata, Tate.
„ lamellata, Tate.
Cardita polynema, Tate.
„ delicatula, Tate.

Cardium victoriae, Tate.
Pinna cordata, Pritchard?
Fossularca equidens, Tate.
Trigonia subundulata, Jenkins.
Limopsis insolita, G. B. Sow.
Dimya sigillata, Tate.
Meretrix tenuis, Tate.
Tellina masoni, Tate.
Corbula pixidata, Tate.

Gastropoda.

Natica wintlei, Tate.
Voluta anticingulata, McCoy.
Turritella aldingae, Tate.
„ conspicabilis, Tate.
Fusus acanthostephes, Tate.
Lotorium tortirostris, Tate
Marginella wentworthi, T. Woods.
Borsonia otwayensis, Tate.
Scalaria pleiophylla, Tate.
Mesalia stylacris, Tate?
Dentalium mantelli, Zittel.
„ subfissura, Tate.

The whole of these fossils occur in the "4ft. of grey sandy clay, rich in fossils" mentioned above in the description of the section.

For 250 yards along the beach to the north-west the clay beds are covered by loose sand and dune rock when the next outcrop of eocene rocks is met with.

Wilkinson's No. 3 Locality.

The rock, a gritty polyzoal limestone, shows as a small cliff 20ft. high, from which a platform runs seawards with westerly facing scarp which extends breast high above the sand and which has to be climbed over when going along the coast. The dip is N. 40° W. at 12°.

From here to Castle Cove the beach is formed of huge blocks of dune rock and progress is slow and painful, as the rock weathers into very hard jagged points.

The following fossils were found at this place (No. 3):—

Corals.

Graphularia senescens, Tate.

Echinoidea.

Scutellina patella, Tate.
Lovenia forbesi, Woods and Duncan.
Echinobrissus vincentianus, Tate.
Cassidulus australiae, Duncan (Echinobrissus).

Brachiopoda.

Magellania grandis, T. Woods.
„ garibaldiana, Davidson.
Magasella compta, G. B. Sowerby.
Terebratulina catinuliformis, Tate.
Crania quadrangularis, Tate.
Rhynchonella squamosa, Hutton.

Lamellibranchiata.

Pecten foulcheri, T. Woods.
„ murrayanus, Tate.
„ yahlensis *var* semilaevis, McCoy.
„ hochstetteri, Zittel.
„ peroni, Tate.
Hinnites corioensis, McCoy.
Limatula jeffreysiana, Tate.
Spondylus pseudoradula, McCoy.
„ gæderopoides, McCoy.

Mammalia.

Squalodon wilkinsoni, McCoy.

Note.—Wilkinson, who found the specimen, says this is the locality where the type of Squalodon wilkinsoni was found. Sir Frederick McCoy quotes it as from Castle Cove, which of course is quite close at hand.

Castle Cove (Wilkinson's No. 5).

The fossiliferous rocks here form a cliff 30ft. high scantily overgrown with small shrubs, and extend for about one and a half chains along the beach. The dip is E. 38° S. and varies in amount from 35° to 40°. The lowermost beds consist of grey clays in thin irregular beds intercalated with hard detrital limestone consisting of comminuted fragments of polyzoa and shells. The limestones become more persistent as we pass up and are here full of brachiopods and joints of Pentacrinus, becoming more ferruginous at a higher level and containing numerous small

quartz pebbles. Overlying the limestones, and apparently conformable to them, is a series of unfossiliferous grey sands with plentiful spangles of white mica up to a quarter of an inch in diameter. These pass up into hard ferruginous grits which dip to sea level on the east and cap the mesozoic rocks on the west. Though apparently quite conformable to the high dipping Eocene it is possible that these grits are much younger than they. If they are Eocene then much of the inland gravel and grit capping of the mesozoic with which they seem continuous will be far older than Wilkinson considered it. The actual junction of the fossiliferous beds with the mesozoic is hidden by drifting sand, and over this the path to the beach passes.

An examination of the list of fossils from this locality shows that a number hitherto known only from Aldinga occur, while at the same time the relationship to the Spring Creek lower beds is pronounced; in fact the Castle Cove section emphasises the close faunal resemblance between Spring Creek and Aldinga.

The fossils occurring are as follows:—

Corals.

Flabellum distinctum, Edw. and Haime.

Echinoidea.

Leiocidaris australis, Duncan.

Cassidulus australiæ, Duncan. [(Echinobrissus) Type locality.]

Eupatagus coranguinum, Tate.

Hemiaster planedeclivis, Gregory.

Crinoidea.

Pentacrinus stellatus, Hutton.

Brachiopoda.

Terebratulina triangularis, Tate.

Magellania pectoralis, Tate.

,, insolita, Tate.

,, tateana, T. Woods.

Crania quadrangularis, Tate.

Terebratula aldingæ, Tate.

Lamellibranchiata.

Gryphaea tarda, Hutton.

Pecten peroni, Tate.

,, yahlensis, T. Woods.

Chione cainozoica, T. Woods.

Chione halli, Pritchard.
Cardita polynema, Tate.
Myadora lamellata, Tate.

Cape Otway.

A list of fossils from this locality has been published and discussed by Messrs. Tate and Dennant, and the beach exposure was briefly described by them (12 and 13). Inland from the coast about half a square mile of swampy land occurs surrounded by high sand dunes. The streams draining from these swamps run over the sea front of the beds which consist entirely of slipped material which has in places flowed out like thick porridge and in this are mingled dune rock, recent shells blown up from the beach and fossils. The only eocene rock we could find *in situ* was about 200 yards from the beach where a small runnel had cut down through the peaty soil to yellow clay with a few fossils in it; but no sign of stratification could be seen owing to the small extent of the exposure.

On the coast-line the mesozoic rocks rise sharply to the south-east and above the level of the eocenes and occupy the coast-line as far as Point Castries, some six miles north-east of Lorne.

An examination of the details given above of the beds exposed at Wilkinson's No. 4 locality will show that during the deposition of the series there, a gradual shallowing of the water took place. The lowermost beds are fine grained and compact and almost the only fossils are beautifully perfect pieces of polyzoa, the long delicate branches of which are unbroken, thus pointing to comparatively undisturbed depths. As we pass up through the series the rocks become coarser till we reach the uppermost beds exposed, the polyzoal limestone, which is full of quartz grit and rounded pebbles. Thus we see that a polyzoal limestone may be deposited in quite shallow water close to land and we may then consider what evidence there is that the limestones of our tertiary beds represent deep water deposits and that the clays represent strata laid down at lesser depths, a conclusion arrived at by Duncan and adopted by many subsequent writers. Our polyzoal limestones are composed of fragments of all sorts and

mostly broken into small pieces. Foraminifera are frequently common, and occasionally constitute the bulk of the rock, as at Batesford and the Grange Burn where the large Orbitoides and Nummulites lie at all angles. In other places fragments of polyzoa form the mass of the beds, with scattered and frequently worn spines of echini, joints of isis, brachiopods and the like. Echinoids, when unbroken, are as often upside down as not and in fact as far as the condition of the organic remains is concerned it points to deposition in shallow water where considerable movement has taken place. But besides this in almost every place where a careful description of the rock has been given we find undoubted traces of coarse detrital matter derived from the land. At Waurn Ponds coarse grits and sandy clays are intercalated with the limestone. Fragments of felspar, quartz and mica are common, derived evidently from the granite area which is partly exposed a few miles to the north-west, and in places the rock is well current-bedded, a feature clearly displayed in many of the blocks of this widely used building stone. At Batesford the polyzoal limestone passes down in places into current-bedded orbitoides limestone and this in its lower part rests on granite and contains numerous granite pebbles. The Lower Maude limestones, which are polyzoal in places, pass down into sands and conglomerates, while the similar limestones of the upper beds contain rounded boulders and pebbles of the underlying volcanic rock. Exactly the same features are shown in the cliffs at Airey's Inlet where an eroded volcanic rock underlies the polyzoal limestone which fills deep pockets and chasms in its surface. On the Grange Burn, near Hamilton, the limestone again is plastered down into the crevices and clefts of the igneous rock. The same thing again occurs at Flinders, Curlewis and Keilor, in fact in almost every place where the underlying beds are exposed we find that polyzoal limestone was the first deposit to be laid down, and even when the basalt beds cannot be seen quartz grit is present in the calcareous beds, as at Aldinga, Spring Creek, Shelford, Point Addis. There are of course places where the contact of the eocene with the underlying older rocks is seen and yet no limestone is found, as at Royal Park and Table Cape, but this in no way detracts from our contention for the shallow-water nature of the polyzoal limestone.

Professor Martin Duncan in speaking of our tertiary rocks says: "Pure limestone, except in the upper part of the series is rare; it contains there an abundance of polyzoa, and is a deep-sea deposit" (7, p. 286). In considering that part of this statement with which we are at present dealing, it must be borne in mind that ideas as to what constitutes a deep-sea deposit have greatly changed since Duncan wrote this, nearly thirty years ago. In the same volume of the Quarterly Journal his remarks show (pp. 54 and 70) that he applies the term deep-sea deposit to anything over ten fathoms, while for the great depths, then being for the first time explored, he would employ the term abyssal.

The organisms, of which the remains constitute the bulk of the rock, probably lived in places where, though the water might be many fathoms deep, yet strong currents prevailed, just as at present the strongly calcareous polyzoa exist in the greatest profusion with us at such places as Port Phillip Heads and the entrance to Western Port, where the tide-current runs most strongly and deposition of fine sediment cannot take place. Limestones of a similar nature are now forming apparently in the shallow waters in the neighbourhood of coral atolls as described by Dana (19, p. 121), and more especially by subsequent writers on the Lagoon of Funafuti. Professor T. W. Edgeworth David has told us orally that the floor of the lagoon is in many places covered with a thick deposit of foraminifera which are even now in parts being cemented into a solid rock. There is nothing then in the nature of the organisms, the remains of which build up our polyzoal limestone, and the foraminiferal limestone into which it in many places passes, which demands deep water for their growth, while the physical nature of the deposit, composed as it is of worn and broken fragments of considerable size, is clearly an indication of its formation in very shallow water or in places where strong currents run.

One of the most interesting points about the eocenes of the Aire, is the existence close together of two clearly distinct faunas. The fauna at the Otway section has been already dealt with by Messrs. Tate and Dennant, and its strong likeness to that of Aldinga has been noted by them (12, p. 113), and the Castle Cove section belongs to the same horizon. In contrast to the fauna of these beds is that displayed at Fishing

Point, which resembles that of Fyansford and Mornington, a resemblance which it is interesting to note, is already recorded by Mr. Reginald Murray in his Geology of Victoria, where he calls the beds about a mile inland, on the east side of the Aire, oligocene (11, p. 101), while he calls the other tertiary beds of the district, miocene (11, p. 103). Both sets are now generally regarded as eocene, though differences in the faunas exist.

As regards the relationships of the two sets of beds, the sections in this locality supply no conclusive evidence, since no junction is visible. The fact that the sections on the coast, near Castle Cove, are acutely folded, and show great variations in strike at the three localities, might be taken as evidence that the horizontal beds of Fishing Point unconformably overlie them. The Castle Cove series is undoubtedly the older, but it is more probable that the disturbance of the beds is merely a local phenomenon, and that the subsequently removed upper series partook in the folding, which ensued close to the flanks of the mesozoic. Whether a similar disturbance took place on the Otway side of the eocene is uncertain, as no clear outcrop of rock *in situ* is visible.

Evidence as to the succession of the beds then not being available here, we must look elsewhere for it, and we find it, as we have previously shown in the Moorabool Valley, where strata, with a strong Spring Creek facies, underlie the oligocene of the survey. We subsequently grouped the Aldingan and Otway beds with those of Spring Creek. Our opinions were objected to by Messrs. Tate and Dennant, who, in the same paper, arrived at the conclusion that the Aldingan and Otway beds represented an age anterior to that at which the Lower Muddy Creek beds were deposited, thus essentially agreeing with our previously published remarks.

The Newer Rocks.

There is nothing much as yet to be added to Wilkinson's remarks on the newer rocks as displayed in the Otway district. The pliocene of the survey, the greater part of which is now generally regarded as miocene, has not hitherto yielded any fossils in this locality, and is apparently ascribed to pliocene age on strati-

graphical evidence only. Wilkinson says (5, p. 25) that: "it occurs at intervals all round the Otway Coast Range, resting on the flanks of it, and at greater elevations than the older tertiary just described, though I have not observed it at a greater altitude than about 1,000 feet above the sea. South of the Dividing Range, we first meet with it at Point Bunbury, Apollo Bay; thence it continues westward to Moonlight Head, capping, more or less, the intervening ranges from one to six miles inland. From Moonlight Head it extends nearly as far west as Warrnambool, resting unconformably on the miocene (*i.e.*, of the survey, H. and P.!) On the north side of the Coast Range we have it, until it passes under the lava plains." He then describes the variations in the deposit in different localities, and mentions a curious coarse conglomerate, which occurs about ten miles up the Gellibrand, and which consists of granite, porphyry, mica-schist, quartzite, and very little true quartz. As far as is known there are no outcrops of ancient rocks in the Otway Ranges which could yield a conglomerate of this nature, in fact, its character as far as can be judged from this brief description, is such as we should expect to find in beds derived from the widely spread palæozoic glacial conglomerate of the southern parts of Australia, a fact to which one of us has previously drawn attention (20, p. 174).

With regard to the dune rock and the sand dunes, Wilkinson's descriptions are very full and accurate. He refers them to post pliocene age in his report and section. Duncan (7, p. 291) reproduces a part of this section, but in the legend omits the words, "post pliocene;" after "*b.* irregularly stratified yellow calcareous sandstones;" moreover, "*h.* brown sand," should read "blown sand." Wilkinson on page 23 of his report, speaks of the dune rock as "more recent tertiary sandstone," evidently regarding the post pliocene formation as a sub-division of the tertiary, a point in which he is of course in agreement with many recent geologists. In his letter to Aplin (4, p. 14), in speaking of these beds, he says: "the bed of lignite is of too limited extent to be of any economic value. It appears to be of very recent tertiary age, and the thick deposit of irregularly laminated calcareous sandstone which overlies it, I believe to be consolidated blown sand." In his report (5, p. 24) he says:

"This" (*i.e.*, 'post pliocene formation' H. and P!) is of no very great extent until we get to Warrnambool, which town is built on it. . . . South of a line drawn about a mile and three-quarters up the Parker River to a point about three-quarters of a mile up the Aire River, and the piece of land between that portion of the Aire Marsh through which the Ford River runs, and the coast as far west as Castle Cove, may be taken as the extent of this deposit at Cape Otway." Further particulars are given of the deposit as far west as Warrnambool, and for these as well as for remarks on the estuary deposits and sand dunes of the coast, reference must be made to his report.

SUMMARY.

The eocene beds of the Aire and Cape Otway occupy a small triangular area of about six square miles. For the greater part of their extent they are hidden by more recent deposits, which for the most part consist of estuarine or æolian beds so that the only outcrops are on the shore line or along the hills which bound the Aire Marsh. On their east and north-west borders they are hemmed in by the fresh-water mesozoic rocks of the Cape Otway series, which rise high above them as lofty hills, so that they perhaps owe their present position to faulting. The beds on the shore line near Cape Flinders, which are generally spoken of as the Cape Otway beds, and those in the neighbourhood of Castle Cove are older than those bordering on the Aire Marsh, the faunas of the two being in strong contrast. The occurrence of these two faunas so close together in the same neighbourhood shows that the differences between them are not due, as has been suggested, to geographical position, while as the lithological characters of the deposits show no striking contrasts, it cannot be that these differences are due to bathymetrical conditions. It follows then that the differences are dependent on difference in age, a point on which we have always insisted in our discussions on the sequence of our eocene strata. The disturbed condition of the deposits in the neighbourhood of Castle Cove, with their high dip and varying strike, possibly affords evidence that they underlie the horizontal beds displayed in the river sections, and if so this evidence is in accord with

that which we found at Maude and which led us to place the Spring Creek series beneath that of Mornington and Muddy Creek, this being the reverse of the reading of the old Geological Survey.

A discussion of the character of the polyzoal limestones leads us to the opinion that they are essentially a shallow water deposit, and not, as has been usually stated, the deep water representative of the argillaceous beds.

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EXPLANATION OF MAP.

1. Otway Section.
2. Fishing Point.
3. Aire Limestones.
4. Spud Point.
5. Aire Coastal Sections.
6. Aire Cattle Station Homestead (Robinson's).